IPSILATERAL HIP AND KNEE IMPLANTS NOT INCREASE BONE FRACTURE RISK: A COMPUTATIONAL STUDY

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1. INTRODUCTION

A rising number [1] of primary hip and knee prosthesis replacements increases the incidence of (small) interprosthetic (IP) gaps between the distal tip of a total hip prosthesis (THA) and the proximal tip of a total knee (TKA) prosthesis. IP gaps influence the biomechanical response of the femur to mechanical load. It has been hypothesized that IP gaps may act as stress risers [2], hence, may lead to increased fracture risk. Yet, it is not well understood how IP gaps affect local bone stresses and strains. The aim of this work was to enhance our understanding of the role of IP gaps on bone strain and to quantify whether they act as stress risers.

Keyword(s): biomechanics – implants

2. METHODOLOGY

A finite element model was created based on a 3D-model of a synthetic femur (Sawbones, Pacific Research Laboratories, Mälmo, Sweden) combined with 3D-models of a primary hip prosthesis or revision hip prosthesis and a knee prosthesis stem (C-stem, Depuy J&J, Warsaw, Indiana, Exeter-stem, Stryker, Kalamazoo, Michigan and Profix, Smith&Nephew, Memphis, Tennessee respectively). These 3D-models were used to simulate the anatomical appearance of an ipsi-lateral prosthesis placement in the femur. Young's modulus was 220 GPa, 110 GPa and 2.13 GPa for THA, TKA, and trabecular bone and intramedullary space, respectively. Cortical bone was modelled as transversely isotropic, resulting in a Young's modulus of 17 GPa along the femoral axis, and 11.5 GPa in the transverse plane. Poisson ratio (ν) was 0.3 for all parts, with the exception for the cortical transverse plane (ν = 0.51).

An anatomically relevant load mimicking walking was applied to the femoral head, trochanter major and lateral side of the trochanter minor, representing the attachment locations of three relevant muscle groups [3]. Abaqus software (6.13, Dassault Systèmes, USA) was used to quantify the stresses and strains along the medial and lateral side of the femoral shaft resulting from the applied loads.

All models were meshed with quadratic elastic tetrahedral elements (C3D10). Convergence analysis showed that an element size of 1.25 mm was appropriate. Both THA and TKA size were varied, resulting in a variation of IP gap size as well as IP gap location.

3. RESULTS

Strains in the IP gap region were higher than those in the surrounding area. The size of the hip prosthesis influenced strains: a model with a primary THA only (140mm) had strains that were 10.6% and 10.5% higher than those of revision THA of 220mm or 240mm length, respectively. Larger gaps caused higher strains [2]: a 140mm THA with 0, 50, 150 and 200mm IP gaps had strains of 0.00447, 0.00464, 0.00484 and 0.00486 respectively. Gaps larger than 100 mm had nearly identical strain patterns and strain maxima.

4. DISCUSSION

The presence of prostheses influenced the bending modulus, hence, affected the strains that occurred in the femur. This effect decreased with decreasing prostheses lengths, hence, with increasing gap size.

5. CONCLUSION

The anatomical model, loaded with a physiological loading condition, showed that not only the gap size, but also the gap location plays an important role in the strain pattern. Additionally, the shape of the prosthesis can also contribute to higher strains. The IP gap does not act as a stress riser, and smaller gaps are favorable.

References

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